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Soft Diffraction and Forward Multiplicity Measurements with TOTEM

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A summary of recent TOTEM double diffraction and charged particle pseudorapidity density results is given, and single diffraction results are also discussed.

1 Introduction

Diffraction scattering represents a unique tool for investigating the dynamics of strong interactions and proton structure. Diffractive events are dominated by soft processes which cannot be calculated with perturbative QCD. Various model calculations predict diffractive cross-sections that are markedly different at the LHC energies [1, 2, 3].

Single diffraction (SD) is the process in which two colliding hadrons interact inelastically, one proton staying intact while the other dissociates to a hadronic system. The interaction is mediated by an object with the quantum numbers of the vacuum. Experimentally, SD has a signature of a final state proton opposite a diffractive system with a rapidity gap in between that is large compared to random multiplicity fluctuations. Rapidity gaps are exponentially suppressed in non-diffractive (ND) events [4]. Double diffraction (DD) is a similar process in which both colliding hadrons dissociate into hadronic systems. Here the signature is two forward hadronic systems on opposite sides separated by a rapidity gap. In Central Diffraction (CD) both protons survive, and the mediating objects fuse to form a central system separated by rapidity gaps from both protons.

1.1 TOTEM

The TOTEM experiment [5] is a dedicated experiment to study diffraction, elastic scattering and the total cross-section at the LHC. It has three subdetectors placed symmetrically on both sides of the interaction point: Roman Pot detectors to identify leading protons and T1 and T2 telescopes to detect charged particles in the forward region. T2 consists of Gas Electron Multiplier chambers that detect charged particles with $p_T > 40$ MeV/c at pseudo-rapidities¹ of $5.3 < |\eta| < 6.5$. The T1 telescope consists of Cathode Strip Chambers that measure charged particles with $p_T > 100$ MeV/c at $3.1 < |\eta| < 4.7$. The Roman pots (RP) are silicon strip detectors at 220m from the interaction point, housed in a moveable “pot” that can approach the beam very closely. The RPs measure scattered protons : with special LHC optics ($\beta^* = 90$ m) they can detect a proton with any amount of momentum loss for vertical momentum transfers larger than $|t_y| > 0.005$ GeV².

¹ $\eta = -\ln[\tan(\theta/2)]$ where θ is the polar angle.

	$6.5 > \eta_{\min}^+ > 4.7$ $-6.5 < \eta_{\min}^- < -4.7$	$5.9 > \eta_{\min}^+ > 4.7$ $-5.9 < \eta_{\min}^- < -4.7$	$6.5 > \eta_{\min}^+ > 5.9$ $-6.5 < \eta_{\min}^- < -5.9$	$5.9 > \eta_{\min}^+ > 4.7$ $-6.5 < \eta_{\min}^- < -5.9$	$6.5 > \eta_{\min}^+ > 5.9$ $-5.9 < \eta_{\min}^- < -4.7$
TOTEM	116 ± 25	65 ± 20	12 ± 5	26 ± 5	27 ± 5
Pythia	159	70	17	36	36
Phojet	101	44	12	23	23

Table 1: Double diffractive cross-section measurements (μb) in the forward region. The measurements (that were corrected separately for the different ranges in η_{\min}) are given and compared to Pythia and Phojet predictions. Pythia estimate for total $\sigma_{DD}=8.1$ mb and Phojet estimate $\sigma_{DD}=3.9$ mb.

The diffractive analyses (DD and SD) use proton-proton collision data that TOTEM took in 2011 at 7 TeV, with $\beta^* = 90\text{m}$, while the $dN/d\eta$ measurement uses a special run with $\beta^* = 3.5\text{m}$ and low pileup, also taken at 7 TeV in 2011.

2 Double diffraction

In this measurement [8], the double diffractive cross-section was determined in the forward region. The DD events were selected by vetoing T1 tracks and requiring tracks in T2, hence selecting events that have two diffractive systems with $4.7 < |\eta|_{\min} < 6.5$, where η_{\min} is the minimum pseudorapidity of all primary particles produced in the diffractive system. Although these events are only about 3% of the total σ_{DD} , they provide a pure selection of DD events and the measurement is an important step towards determining if there is a rich resonance structure in the low mass region [6]. To probe further, the η_{\min} range was divided into two halves on each side (at $|\eta| = 5.9$), providing four subcategories for the measurement.

First, the raw rate of double diffractive events is estimated: the selected sample is corrected for trigger efficiency, pile-up and T1 multiplicity, and the amount of background is determined. Second, the visible cross-section is calculated by correcting the raw rate for acceptance and efficiency to detect particles. Lastly, the visible cross-section is corrected so that both diffractive systems have $4.7 < |\eta|_{\min} < 6.5$. Three kinds of background were considered for the analysis: ND, SD and CD. The data-driven ND and SD background estimation methods were developed to minimize the model dependence, and the values of the background estimates were calculated iteratively. Since the CD background is significantly smaller than the ND and SD ones, its estimate was taken from simulation, using the acceptance and $\sigma_{CD}=1.3$ mb from Phojet [7]. The results for the DD cross section are shown in Table 1.

3 Single diffraction

In this preliminary measurement SD events (proton + gap + hadronic system) are selected using the RPs and T2. We require exactly one proton, with a rapidity gap in one T2 on the same side as the proton, and T2 tracks on the opposite side. T2 is used as trigger. The gap size from the proton to the nearest track in T1 or T2 corresponds to diffractive mass ranges given in Table 2.

The raw rate was first corrected for T2 trigger efficiency and RP acceptance. Then we subtracted the independent 2-proton background, the pileup of a proton in RP from the beam halo (or $M_{SD} < 3$ GeV) with a non-related minimum bias event in T2, and corrected for the probability of the proton producing a shower within the RP station (not reconstructed

SD class	Inelastic telescope configuration	Mass range	Momentum loss (ξ)
Low mass	T2 opposite p only (no T1)	3.4 – 8 GeV	$2 * 10^{-7} - 10^{-6}$
Medium mass	T2 opposite p + T1 opposite p	8 – 350 GeV	$10^{-6} - 0.25\%$
High mass	T2 opposite p + T1 same side as p	0.35 – 1.1 TeV	$0.25\% - 2.5\%$

Table 2: SD classes used

as a single track). This gave an estimate of the SD signal. Migration between rapidity gap categories, beam divergence corrections, and momentum loss resolution effects on the mass spectrum still have to be taken into account.

The final goal of this analysis is to measure, for each mass bin (ξ -bin) in Table 2, the integrated cross section, the differential spectrum $d\sigma/dt$, and a fitted exponential slope for the spectrum. If there are any visible effects of low mass resonances [6], they will affect what the spectrum looks like at the smallest t -values; the spectrum may turn down, or have a dip with respect to the fitted exponential.

4 Differential charged particle density

The TOTEM experiment has measured [9] the charged particle pseudorapidity density $dN_{\text{ch}}/d\eta$ in pp collisions at $\sqrt{s} = 7$ TeV for $5.3 < |\eta| < 6.4$ in events with at least one charged particle with transverse momentum above 40 MeV/c in this pseudorapidity range. This extends the analogous measurement performed by the other LHC experiments to the previously unexplored forward η region. The measurement refers to more than 99% of non-diffractive processes and to single and double diffractive processes with diffractive masses above ~ 3.4 GeV, corresponding to about 95% of the total inelastic cross-section. The $dN_{\text{ch}}/d\eta$ is found to decrease with $|\eta|$, from $3.84 \pm 0.01(\text{stat}) \pm 0.37(\text{syst})$ at $|\eta| = 5.375$ to $2.38 \pm 0.01(\text{stat}) \pm 0.21(\text{syst})$ at $|\eta| = 6.375$. Several MC generators are compared to data; none of them are found to fully describe the measurement.

TOTEM is presently [10] finalizing with CMS an article about a combined measurement at 8 TeV, based on a common run with integrated data taking in 2012.

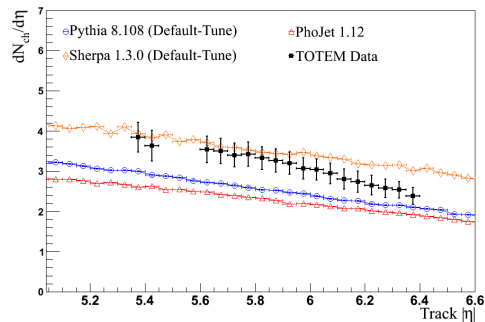


Figure 1: Differential distribution in pseudorapidity. Experimental points (black squares) are the average of the four T2 quarters. Error bars include statistical and systematic errors. Red triangles, blue circles and orange diamonds are: the Phojet, Pythia8 and Sherpa predictions for charged particles with $P_T > 40$ MeV/c in events with ≥ 1 charged particle generated in the $5.3 < |\eta| < 6.5$ range.

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